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TECHNICAL REPORT ARLCD-TR-79018

MINIMUM NON-PROPAGATION DISTANCE FOR 76.2 KG
(168 LB) OF FLAKE TNT IN INTERCONNECTING
BUILDING RAMPS

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LARGE CALIBER
WEAPON SYSTEMS LABORATORY
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This project was accomplished as part of the U.S. Army's Manufacturing Methods and Technology Program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques and equipment for use in the production of Army materiel.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Minimum non-propagation distance
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
A series of tests were performed to establish the minimum non-propagation distances between 76.2 kg (168 lb) of flake TNT contained in aluminum tote bins for two types of interconnecting building ramps simulating the actual plant conditions at Holston Army Ammunition Plant, Kinsport, Tennessee. The test results show that the minimum propagation distance for ramps with wood frames and sides is 15.2 meters (50 feet) and for ramps with steel frames and fiberglass sides, it is 18.1 meters (60 feet).

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ACKNOWLEDGMENTS

TABLE OF CONTENTS

INTRODUCTION

Background

At the present time, an Army-wide modernization and expansion program is underway to upgrade existing facilities and develop new explosive manufacturing and Load/Assemble/Pack (LAP) capabilities. This effort will enable the U.S. Army to increase production cost effectiveness with improved safety, as well as to convert existing facilities to the manufacture of new weaponry. As an integral segment of the overall program, the Manufacturing Technology Division of the Large Caliber Weapons System Laboratory (ARRADCOM), Dover, New Jersey, is engaged in the continuous development of safety criteria as an activity entitled "Safety Engineering in Support of Ammunition Plants" for the Project Manager for Munitions Production Base Modernization and Expansion. This activity includes safe separation, non-propagation distance studies of ammunition end-items as well as in-process explosive materials. The criteria developed from these study programs will be used as part of the basis for the design of all explosive production installations due for modernization and will be available for reference to privately owned and operated (POPO) plants engaged in ordnance manufacturing operations.

The activities covered in this report provide safety data criteria to specifically support the modernization and conversion of the Composition B production line at the Holston Army Ammunition Plant, Kingsport, Tennessee, to handle TNT in flake condition. A test program was implemented to simulate the conveyor lines and interconnecting building ramps at Holston which are presently used for Composition B production.

Objective

The primary objective of this segment of the project was to determine experimentally the safe separation, non-propagation distance between 76.2-kilogram (168-pound) quantities of flake TNT being transported between LAP operations in aluminum tote bins by a conveyor system in an interconnecting building ramp. The data derived from this report will be used to establish criteria for container spacing on conveyors, conveyor speeds, and production rates for flake TNT.

The test program consisted of two parts, each encompassing an exploratory and a confirmatory phase. In the first part, wood framed and sided ramps were used to simulate actual

1

interconnecting building ramps; in the second part, the simulated ramps were constructed of steel framing with fiberglass sides. In both cases, the exploratory phase consisted of a series of non-propagation trial and error tests to determine the minimum safe separation distance between aluminum tote bins containing 76.2 kilograms (168 pounds) of flake TNT. The confirmatory phase was implemented to establish statistical confidence in the determined distance.

Criterion

The testing simulated as accurately as possible actual LAP facility conditions. The only acceptable criterion for determining the safe separation distance was the non-propagation of the donor tote bin (initiated charge) detonation to the adjacent acceptor tote bins. Burning of spilled acceptor tote bins was not considered a failure as state-of-the-art water deluge systems can extinguish the burning explosives. Throughout the tests, distances between adjacent tote bins were measured from centerline to centerline.

TEST CONFIGURATION

Testing was initiated in July 1978 and completed during March 1979 at Camp Shelby, Mississippi. All testing was conducted under the auspices of the ARRADCOM Resident Operations Office in conjunction with the Hazards Range Support Unit of Computer Science Corporation, both located at NSTL Station, Mississippi.

The first segment of the two-part test program was conducted in wooden ramps; the second, in steel and fiberglass ramps. Both types of ramps were designed to simulate interconnecting building ramps actually in use at Holston. Each of the two series of tests was further broken down into exploratory and confirmatory phases.

Test Specimens

The test specimens for this study, 76.2 kilograms (168 pounds) each of flake TNT, were tested in aluminum tote bins.

TNT (trinitrotoluene) is an organic flammable toxic derivative of toluene obtained by single-stage nitration. Its chemical composition $[CH_3C_6H_2(NO_2)_3]$ is 37.0% carbon, 2.2% hydrogen, 18.5% percent nitrogen and 42.3% oxygen, with a molecular weight of 227. In ordnance, TNT is used primarily as an explosive filler in GP bombs, HE projectiles, demolition charges, depth charges and grenades; it is also an active ingredient in some propellant charges.

The aluminum tote bin (figs. 1 and 2) is made of 7075-T6 aluminum with a uniform thickness of 3.18 millimeters (0.125 inch). The tote bin is 61.0 centimeters (24.0 inches) long and 45.7 centimeters (18.0 inches) in width and overall height. It is a five-sided container with a textolite or plexiglass hinged lid covering an opening 20.4 centimeters (13.25 inches) by 40.0 centimeters (15.75 inches).

Test Arrangements

For each test firing, three specimen bins (one donor and two acceptors) were arranged in a straight line in the simulated ramp. Each bin was placed on a 1.52-meter (5.0-foot) pedestal to simulate the distance between the conveyor and the ramp floor. The center specimen served as the donor while the two other specimens, located at each end of the ramp, served as the acceptors. This arrangement produced two sets of acceptor

3

results for each donor detonated, and also insured proper donor detonation confinement by centering that specimen in the ramp. The separation distances between the donor and acceptor specimens were varied from test to test, even within a single test firing during the exploratory test phase; however, the distances were held constant during confirmatory testing.

The tote bins were aligned as they would be on the actual conveyor line, with the front of the bin facing the side of the ramp (top hinges aligned with the ramp's axis) and the tops closed.

The wooden ramps used in the first part of the test program were 2.4 meters (8 feet) in both width and height, and varied in length from 14.6 meters (48 feet) to a maximum of 39 meters (139 feet). The ramps were designed to insure complete containment of all three test specimens. Ramp lengths for various donor-to-acceptor tests are given in table 1. The ramps were constructed on the test site as needed from prefab modular wall and roof sections (fig. 3). Each wall was constructed of wooden 2-by-4's covered with sheets of wooden paneling 6.4 millimeters (0.25 inch) thick. The paneling was attached to the inside of the wooden frame to insure that the detonation would be contained by the strength of the structure and not by how strongly the panels were attached to the framework. As the ramps were built, external braces were attached to the 2-by-4's and driven into the ground. A complete wooden ramp is shown in figure 4. Thirty-six donor specimens were detonated during the two-phase (exploratory and confirmatory) testing of the wooden ramp configuration.

The second part of the test program was virtually the same as the first, except that the simulated ramp was constructed of fiberglass and steel (figs. 5 and 6). Like the wooden ramps tested earlier, the steel fiberglass test structures were 2.4 meters (8 feet) in width and height, and the length varied from a minimum of 12.2 meters (40 feet) to a maximum of 18.1 meters (60 feet). The ramp lengths for the various donor-to-acceptor distances were listed in table 1. The prefab modular wall sections were constructed of 3.8-centimeter by 3.8-centimeter (1.5-inch by 1.5-inch) angle iron, 3.2 millimeters (0.13 inch) thick, covered with corrugated fiberglass panels. Each panel was 0.6 meter by 2.4 meters (2 feet by 8 feet) by 0.89 millimeter (0.035 inch) thick. When the ramps were built, three prefab panels were welded together to form a modular section; then one section was welded to the next until the desired length was reached. The wall sections were sealed by overlapping the panels by one corrugation. The completed ramp (fig. 6) was secured in position by braces in the same manner as the wooden ramp. A

4

total of 35 tests were conducted in the steel and fiberglass ramps during exploratory and confirmatory testing.

Method of Initiation

The donor tote bins used throughout the testing contained 76.2 kilograms (168 pounds) of flake TNT primed with a conically shaped Composition C4 booster charge, electrically initiated by an engineer's special J2 blasting cap. The Composition C4 booster weighed 1.8 kilograms (4.0 pounds) and was located on top of the flake TNT in the tote bin, directly below the plexiglass cover. This method of initiation was used throughout the test program and, in all cases, produced a high order detonation.

TEST RESULTS

Wooden Ramps

Exploratory Test Phase

NSTL conducted 11 exploratory tests in simulated wooden ramps at Camp Shelby, Mississippi, during October 1978. The results of these tests are shown in table 2 (tests nos. 1 through 11). The separation distances used in this portion of the test program ranged from a minimum of 4.6 meters (15 feet) to a maximum of 22.9 meters (75 feet) with high order donor detonations propagating to the acceptor tote bins at all distances of 12.8 meters (42 feet) or less. Since only minor damage (denting or seam splitting of the acceptor tote bins) occurred at the 15.2-meter (50-foot) distance, that was selected as the minimum non-propagative safe separation distance for the confirmatory test phase. Figures 7 and 8 show post-test views of typical wooden ramps after detonations which propagated to the acceptor bins.

Confirmatory Test Phase

Twenty-six confirmatory tests were performed at the safe separation distance of 15.2 meters (50 feet) between the donor and acceptor specimens (tests 12 through 36, table 2). During these tests, there was some minor damage to the aluminum tote bins, but not one incidence of a donor detonation propagating to an acceptor; in fact, no flame propagation was observed.

Steel and Fiberglass Ramps

Exploratory Test Phase

Ten exploratory tests were conducted at Camp Shelby by NSTL personnel from January to March 1979. The results of these tests (nos. 1 through 10) are shown in table 3. The separation distances used ranged from a minimum of 12.2 meters (40 feet) to a maximum of 18.1 meters (60 feet) with high order donor detonations propagating to the acceptor tote bins at all distances of 15.2 meters (50 feet) or less. Since only minor damage (denting or seam rupturing of the acceptor tote bin) occurred at the 18.1-meter (60-foot) distance, that was selected as the minimum safe separation non-propagation distance for the confirmatory test phase. Figure 9 is a post-test view of a typical steel and fiberglass ramp after detonation. An acceptor damaged in a steel/fiberglass detonation is shown in figure 10.

6

Confirmatory Test Phase

Twenty-five confirmatory tests were performed at the safe separation distance of 18.1 meters (60 feet) between the donor and the acceptor specimens (tests nos. 11 through 35, table 3).

Summary of Test Results

During the wooden ramp phase of the test program, a total of 36 exploratory and confirmatory tests were conducted. Fifty-one data points were derived from the results of these tests, clearly showing that the 15.2-meter (50-foot) separation distance between tote bins was sufficient to prevent propagation of not only the donor detonation, but also flame propagation to any of the TNT in the acceptor units.

During the steel and fiberglass ramp testing, a total of 35 exploratory and confirmatory tests were conducted. Fifty data points were derived from the results of these tests establishing 18.1 meters (60 feet) as the safe separation distance between the specimen donor and acceptor tote bins. This distance was sufficient to prevent propagation of the donor detonation and ignition (by flame) of spilled TNT in the acceptor units.

Analysis of Test Results

Variation in manufacturing tolerances, materials, wear, etc., required that statistical reasoning be enlisted in the interpretation of the test data. The actual probability of the propagation of an explosive incident is a function of the number of propagation occurrences in a particular test phase as related to the total number of tests conducted. (See Appendix for statistical theory.)

In the wooden ramp testing, 51 observations were recorded at the 15.2-meter (50-foot) safe separation non-progagation distance, resulting in an upper limit of 6.98% probability of propagation of an explosive incident at the 95% confidence level.

In the steel and fiberglass ramp test program, 50 observations were recorded at the 18.1-meter (60-foot) safe separation non-propagation distance, resulting in an upper limit of 7.11% probability of propagation of an explosive incident at the 95% confidence level.

7

CONCLUSIONS

It may be concluded from the test results that 76.2-kilogram (168-pound) quantities of flake TNT in aluminum (7075-T6) tote bins can be safely transported on conveyor systems in wooden interconnecting building ramps, provided a distance of 15.2 meters (50 feet) is maintained between tote bins. At this distance, the probability of the propagation of an explosive incident is 6.98% at the 95% confidence level.

Also, test results indicate that 76.2-kilogram (168-pound) quantities of flake TNT in aluminum tote bins can be safely transported on conveyor systems in a steel and fiberglass interconnecting building ramp, provided a distance of 18.1 meters (60.0 feet) is maintained between tote bins. At this distance, the probability of the propagation of an explosive incident is 7.11% at the 95% confidence level.

RECOMMENDATIONS

Since this report is limited to only two of the many interconnecting building ramps currently used (or planned) for the transport of flake TNT, it is recommended that additional tests be conducted on similar test specimens under extreme conditions of confinement.

The most appropriate maximum confinement test is one conducted in a ramp with an angle-iron frame and aluminum sheet side panels. This type of test program would contribute significantly to the data needed to design new interconnecting building ramps for conveyor transport of various types of bulk munitions.

Table 1. Simulated interconnecting building ramp lengths

| Ramp construction | Donor distance to: | | | | | | Total Test length | | Ramp length | |
| | Left acceptor | | Right acceptor | | | | | | | |
	m	(ft)	m	(ft)			m	(ft)	m	(ft)
wood	4.6	(15)	9.2	(30)			13.8	(45)	14.6	(48)
wood	7.6	(25)	7.6	(25)			15.2	(50)	17.1	(56)
wood	9.2	(30)	9.2	(30)			18.4	(60)	19.5	(64)
wood	12.9	(42)	12.8	(42)			25.6	(84)	26.8	(88)
wood	15.2	(50)	15.2	(50)			30.4	(100)	31.7	(104)
wood	15.2	(50)	22.9	(75)			38.1	(125)	39.0	(128)
steel/ fiberglass	12.2	(40)	12.2	(40)			24.4	(80)	26.8	(88)
steel/ fiberglass	15.2	(50)	15.2	(50)			30.4	(100)	31.7	(104)
steel/ fiberglass	18.1	(60)	18.1	(60)			36.2	(120)	39.0	(128)

9

Table 2. Wooden ramp test results

Test No.	Acceptor	Acceptor distance from donor		Percent TNT burned	Tote bin damage	Remarks*
		m	(ft)			
1	Left	15.2	(50.0)	0	Dented	NDP
	Right	22.9	(75.0)	0	None	NDP
2	Left	4.6	(15.0)	NA	Destroyed	HOD
	Right	9.2	(30.0)	100	Melted	NDP, fire
3	Left	6.1	(20.0)	100	Split seams	NDP, fire
	Right	7.6	(25.0)	100	Melted	NDP, fire
4	Left	5.3	(16.5)	NA	Destroyed	HOD
	Right	6.1	(20.0)	100	Split seams	NDP, fire
5	Left	6.9	(22.5)	100	Melted	NDP, fire
	Right	6.9	(22.5)	100	Melted	NDP, fire
6	Left	7.6	(25.0)	0	Dents/splits	NDP
	Right	7.6	(25.0)	0	Heavy damage	NDP
7	Left	7.6	(25.0)	NA	Destroyed	HOD
	Right	7.6	(25.0)	NA	Destroyed	HOD
8	Left	9.2	(30.0)	NA	Destroyed	HOD
	Right	9.2	(30.0)	NA	Destroyed	HOD
9	Left	12.8	(42.0)	0	Dented	NDP
	Right	12.8	(42.0)	0	Split seams	NDP
10	Left	12.8	(42.0)	0	Split seams	NDP
	Right	12.8	(42.0)	0	Split seams	NDP
11	Left	12.8	(42.0)	0	Split seams	NDP
	Right	12.8	(42.0)	NA	Destroyed	HOD
12	Left	15.2	(50.0)	0	Penetrated	NDP
	Right	15.2	(50.0)	0	Dented	NDP

* NDP - No detonation propagation
  HOD - High order detonation

10

Table 2
(continued)

Test No.	Acceptor	Acceptor distance from donor		Percent TNT burned	Tote bin damage	Remarks*
		m	(ft)			
13	Left	15.2	(50)	0	Dented	NDP
	Right	15.2	(50)	0	None	NDP
14	Left	15.2	(50)	0	Dents	NDP
	Right	15.2	(50)	0	Split seams	NDP
15	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	0	None	NDP
16	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	0	Penetrated	NDP
17	Left	15.2	(50)	0	Split seams	NDP
	Right	15.2	(50)	0	Cracks	NDP
18	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	0	Split seams	NDP
19	Left	15.2	(50)	0	None	NDP
	Right	15.2	(50)	0	None	NDP
20	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	0	Dented	NDP
21	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	0	Split seams	NDP
22	Left	15.2	(50)	0	Dented	NDP
	Right	15.2	(50)	0	None	NDP
23	Left	15.2	(50)	0	Split seams	NDP
	Right	15.2	(50)	0	Cracks	NDP
24	Left	15.2	(50)	0	Dents	NDP
	Right	15.2	(50)	0	Split seams	NDP

*NDP - No detonation propagation

11

Table 2
(concluded)

Test No.	Acceptor	Acceptor distance from donor		Percent TNT burned	Tote bin damage	Remarks*
		m	(ft)			
25	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	0	Penetrated	NDP
26	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	0	None	NDP
27	Left	15.2	(50)	0	None	NDP
	Right	15.2	(50)	0	Penetrated	NDP
28	Left	15.2	(50)	0	Split seams	NDP
	Right	15.2	(50)	0	Dents	NDP
29	Left	15.2	(50)	0	None	NDP
	Right	15.2	(50)	0	Dents	NDP
30	Left	15.2	(50)	0	Dented	NDP
	Right	15.2	(50)	0	Split seams	NDP
31	Left	15.2	(50)	0	Cracks	NDP
	Right	15.2	(50)	0	Split seams	NDP
32	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	0	Penetrated	NDP
33	Left	15.2	(50)	0	None	NDP
	Right	15.2	(50)	0	Penetrated	NDP
34	Left	15.2	(50)	0	Dented	NDP
	Right	15.2	(50)	0	None	NDP
35	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	0	Dented	NDP
36	Left	15.2	(50)	0	None	NDP
	Right	15.2	(50)	0	Split seams	NDP

*NDP - No detonation propagation

Table 3. Steel and fiberglass ramp test results

Test No.	Acceptor	Acceptor distance from donor		Percent TNT burned	Tote bin damage	Remarks*
		m	(ft)			
1	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	0	Dented	NDP
2	Left	12.2	(40)	0	None	NDP
	Right	12.2	(40)	NA	Destroyed	HOD
3	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	0	Penetrated	NDP
4	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	100	Melted	NDP
5	Left	15.2	(50)	0	None	NDP
	Right	15.2	(50)	0	None	NDP
6	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	0	None	NDP
7	Left	15.2	(50)	0	Penetrated	NDP
	Right	15.2	(50)	0	None	NDP
8	Left	15.2	(50)	0	None	NDP
	Right	15.2	(50)	0	Dented	NDP
9	Left	15.2	(50)	0	Dented	NDP
	Right	15.2	(50)	0	Destroyed	HOD
10	Left	18.1	(60)	0	Penetrated	NDP
	Right	18.1	(60)	0	None	NDP
11	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	Penetrated	NDP
12	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	Penetrated	NDP

* NDP - No detonation propagation
  HOD - High order detonation

13

Table 3
(continued)

Test No.	Acceptor	Acceptor distance from donor		Percent TNT burned	Tote bin damage	Remarks*
		m	(ft)			
13	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	Dented	NDP
14	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	None	NDP
15	Left	18.1	(60)	0	Dented/ penetrated	NDP
	Right	18.1	(60)	0	None	NDP
16	Left	18.1	(60)	0	Penetrated	NDP
	Right	18.1	(60)	0	Penetrated	NDP
17	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	None	NDP
18	Left	18.1	(60)	0	Penetrated	NDP
	Right	18.1	(60)	0	None	NDP
19	Left	18.1	(60)	0	Penetrated	NDP
	Right	18.1	(60)	0	None	NDP
20	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	Dented	NDP
21	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	None	NDP
22	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	Dented	NDP
23	Left	18.1	(60)	0	Penetrated	NDP
	Right	18.1	(60)	0	Dented/ penetrated	NDP

*NDP - No detonation propagation

14

Table 3
(concluded)

Test No.	Acceptor	Acceptor distance from donor		Percent TNT burned	Tote bin damage	Remarks*
		m	(ft)			
24	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	Dented	NDP
25	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	Large penetration	NDP
26	Left	18.1	(60)	0	Penetrated	NDP
	Right	18.1	(60)	0	None	NDP
27	Left	18.1	(60)	0	Penetrated	NDP
	Right	18.1	(60)	0	Large penetration	NDP
28	Left	18.1	(60)	0	Dented	NDP
	Right	18.1	(60)	0	Dented	NDP
29	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	None	NDP
30	Left	18.1	(60)	0	Penetrated	NDP
	Right	18.1	(60)	0	None	NDP
31	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	Penetrated	NDP
32	Left	18.1	(60)	0	Dented	NDP
	Right	18.1	(60)	0	Penetrated	NDP
33	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	None	NDP
34	Left	18.1	(60)	0	Dented	NDP
	Right	18.1	(60)	0	Dented	NDP
35	Left	18.1	(60)	0	None	NDP
	Right	18.1	(60)	0	None	NDP

*NDP - No detonation propagation

15
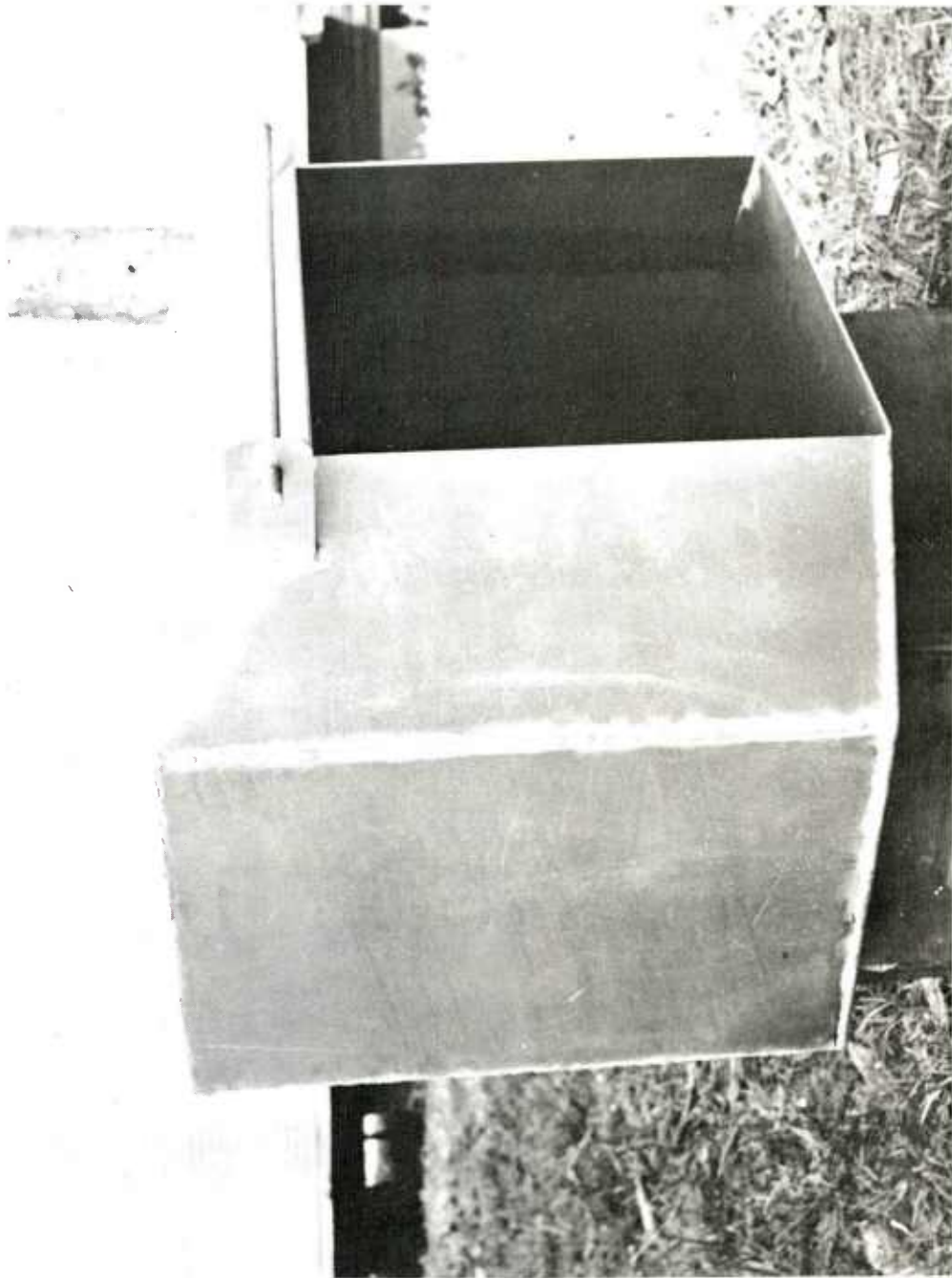
Figure 1. Aluminum tote bin

16

MATERIAL :
3.18mm (⅛") THICK
7075-T6 ALUMINUM
ALL WELDED CONSTRUCTION

TOTE BIN LID PLEXIGLASS SHEET
46.9cm x 40.5cm (18½" x 16")
6.26mm (¼") THICK

45.7cm (18")

20.4cm (13¼")

40.0cm (15¼")

61.0cm (24")

45.7cm (18")

30.2cm (12")
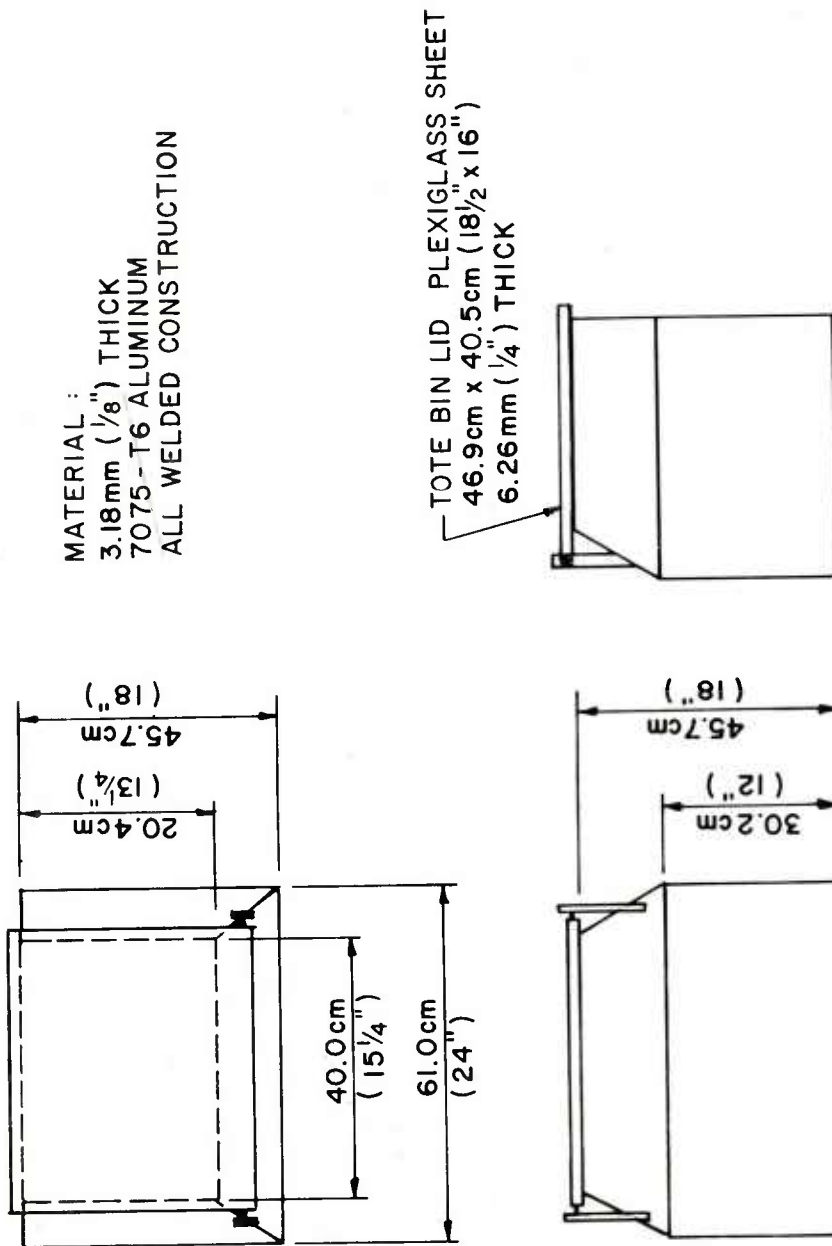
Figure 2. Aluminum tote bin (dimensions)

17

1.2 x 2.4m (4' x 8')
PLYWOOD PANELS

5.1 x 10.2cm (2" x 4")
LUMBER FRAME

SUPPORT

2.4 m
(8'-0")

2.4 m
(8'-0")

2.4 m
(8'-0")
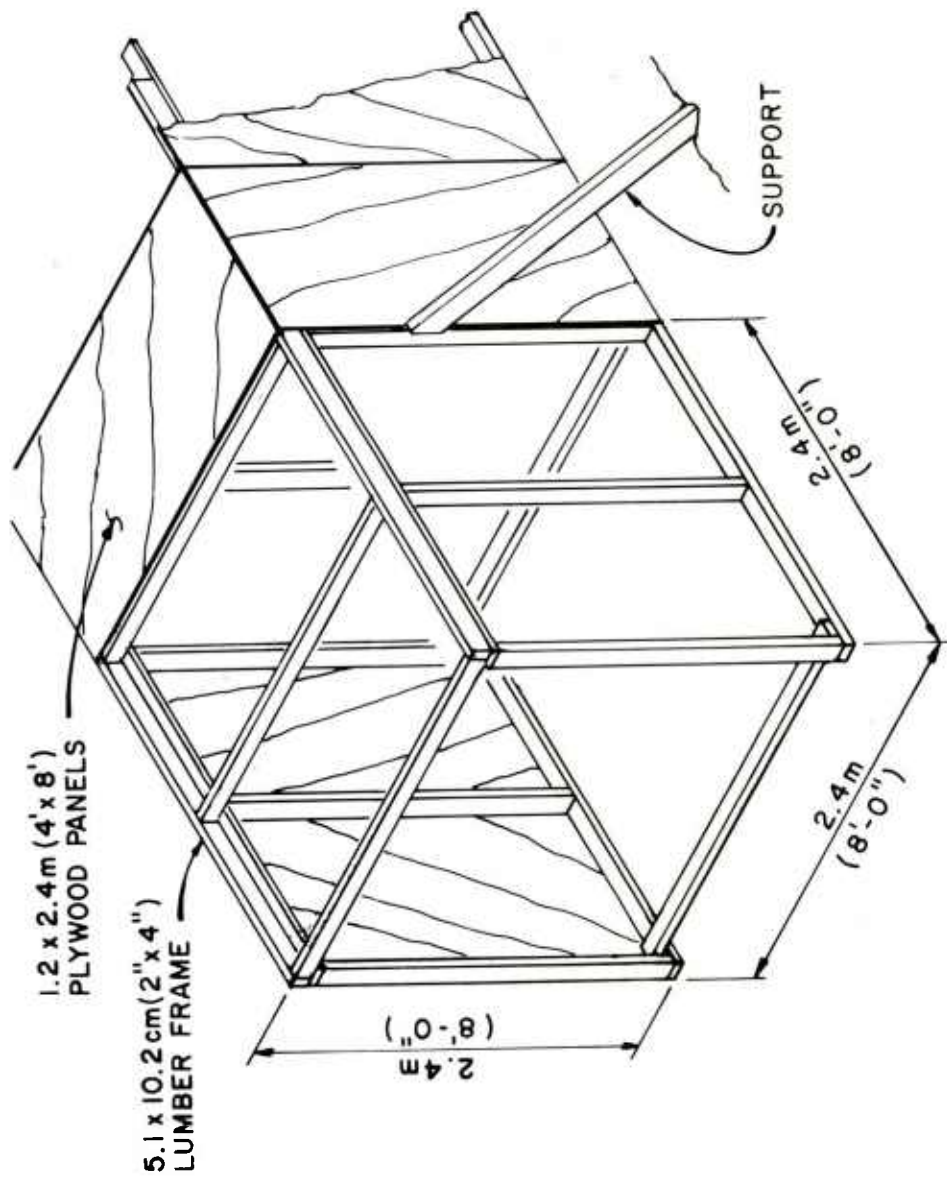
Figure 3.   Modular wood-framed ramp section

18

Figure 4. All wooden ramp

19
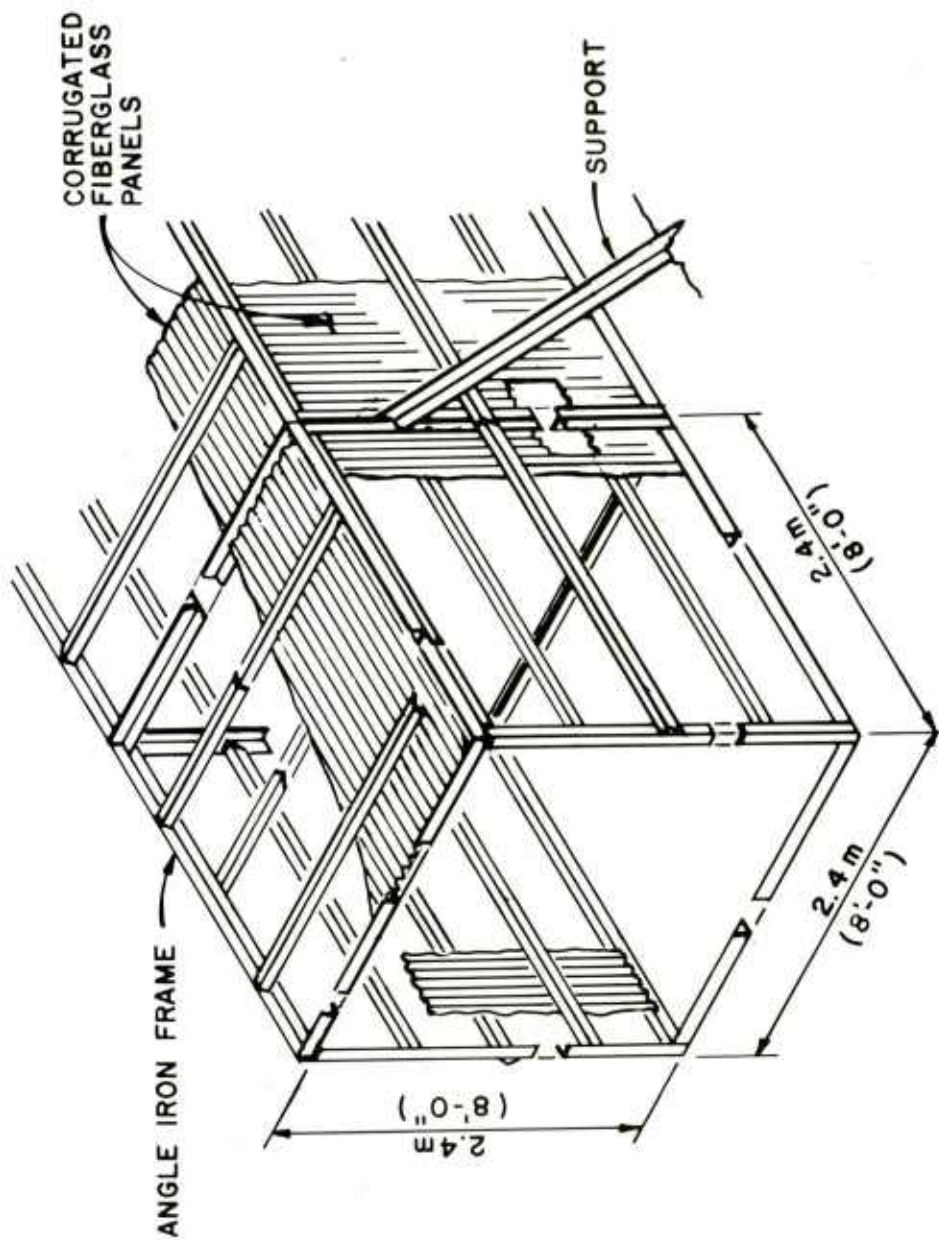
Figure 5. Modular steel-framed ramp section

CORRUGATED FIBERGLASS PANELS

SUPPORT

ANGLE IRON FRAME

2.4 m (8'-0")

2.4 m (8'-0")

2.4 m (8'-0")

Figure 6. Steel and fiberglass ramp

21

Figure 7. Post test general view of wood-framed and wood-sided ramp

Figure 8. Burning acceptor wood-framed and wood-sided ramp

Figure 9. Post test general view of steel-framed and fiberglass-sided ramp

24

TNT FLAKE
SAFE SEPARATION
DISTANCE
168 LBS
4.0 LBS C4
BOOSTER

59 FT 4 INCHES
09 9 25 25
MAR 1979

2
ACCEPTOR

Figure 10. Acceptor damage: steel-framed and fiberglass-sided ramp

APPENDIX. STATISTICAL EVALUATION OF EXPLOSION PROPAGATION

Statistical Theory

The possibility of the occurrence of explosion propagation based upon a statistical analysis of the test results has been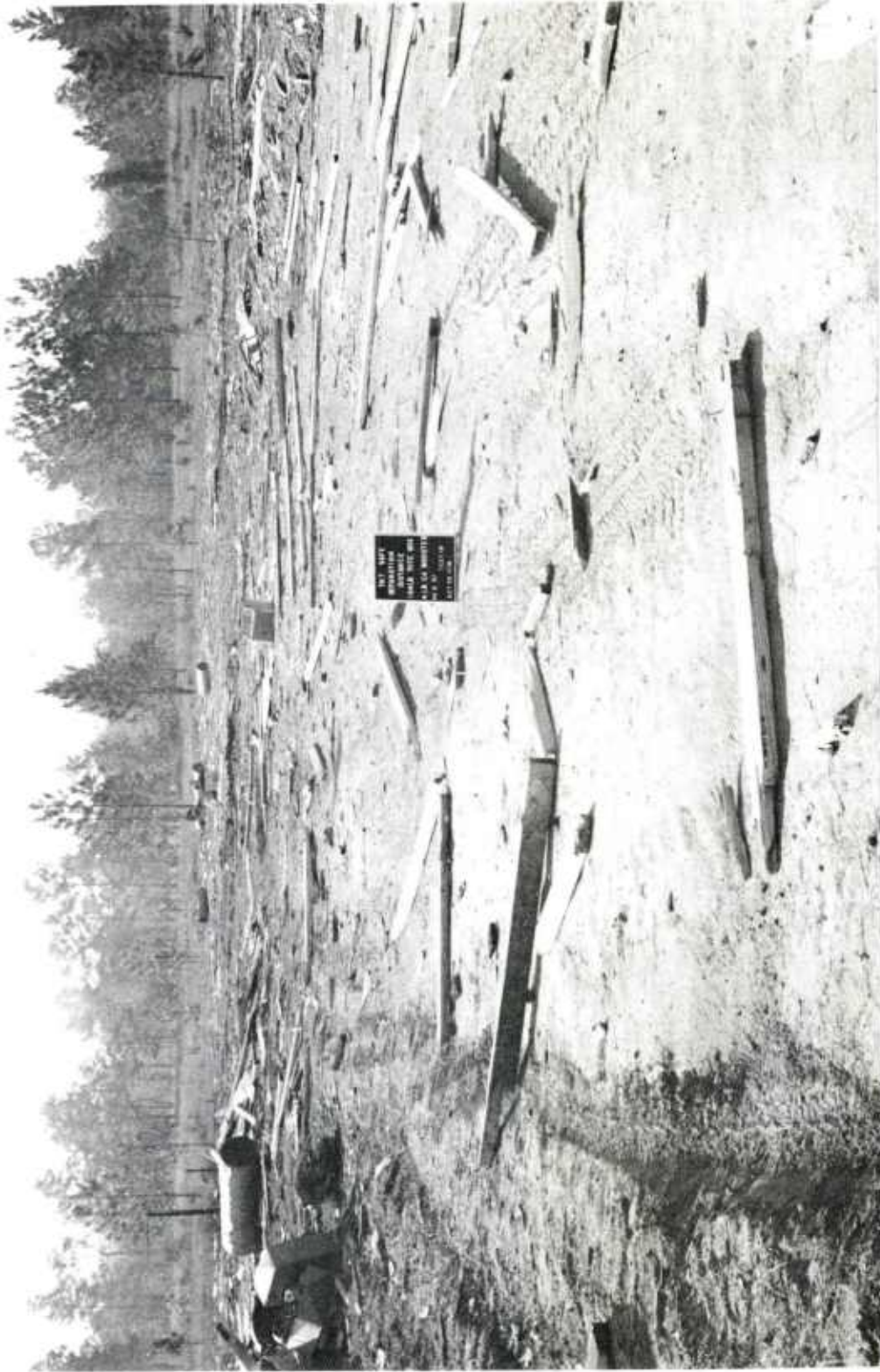 evaluated in the main body of the report. This appendix is devoted to the mathematical means by which the statistical analysis was performed.

The probability of the occurrence of an explosion propagation is dependent upon the degree of certainty or confidence level involved and has upper and lower limits. The lower limit for all confidence levels is zero; whereas the upper limit is a function of the number of observations or, in this particular case, the number of acceptor items tested. Since each observation is independent of the others and each observation has a constant probability of a reaction occurrence (explosion propagation), the number of reactions (x) in a given number of observations (n) will have a binomial distribution. Therefore, the estimate of the probability (p) of a reaction occurrence can be represented mathematically by

$$p = x/n \qquad (1)$$

and, therefore, the expected value of (x) is given by

$$E(x) = np \qquad (2)$$

Each confidence level will have a specific upper limit (p_2) depending upon the number of observations involved. The upper probability limit for a given confidence level α, when a reaction is not observed, is expressed as

$$(1 - p_2)^n = \varepsilon \qquad (3)$$

where
$$\varepsilon = (1 - \alpha)/2 \text{ and } \alpha < 1.0 \qquad (4)$$

Use of equation 3 is illustrated in the following example:

Example

Determine the upper probability limit of the occurrence of an explosion propagation for a confidence level of 95% based upon 30 observations without a reaction occurrence.

27

<u>Given</u>

Number of Observations (n) = 30
Confidence Level (α)   = 95%

<u>Solution</u>

1. Substitute the given value of (α) into equation 4
    and solve for ε:

    $\varepsilon = (1 - \alpha)/2 = (1 - 0.95)/2 = 0.025$

2. Substitute the given value of (n) and value of (ε)
    into equation 3 and solve for p_2:

    $\varepsilon = 0.025 = (1 - p_2)^{30}$

    or

    $p_2 = 0.116(11.6\%)$

<u>Conclusions</u>

For a 95% confidence level and 30 observations, the true
value of the probability of explosion propagation will fall
between zero and 0.116; or statistically, it can be interpreted
that in 30 observations, a maximum of $(0.116 \times 30) = 3.48$
observations could result in a reaction for a 95% confidence
level.

Probability Table

Table A-1 shows the probability limits and the range of the
expected value $E(x)$ for different numbers of observations. Three
confidence limits, 90, 95 and 99%, are used to derive the
probabilities. The same values are plotted in Figure A-1.

28

Table A-1. Probabilities of propagation for various confidence limits

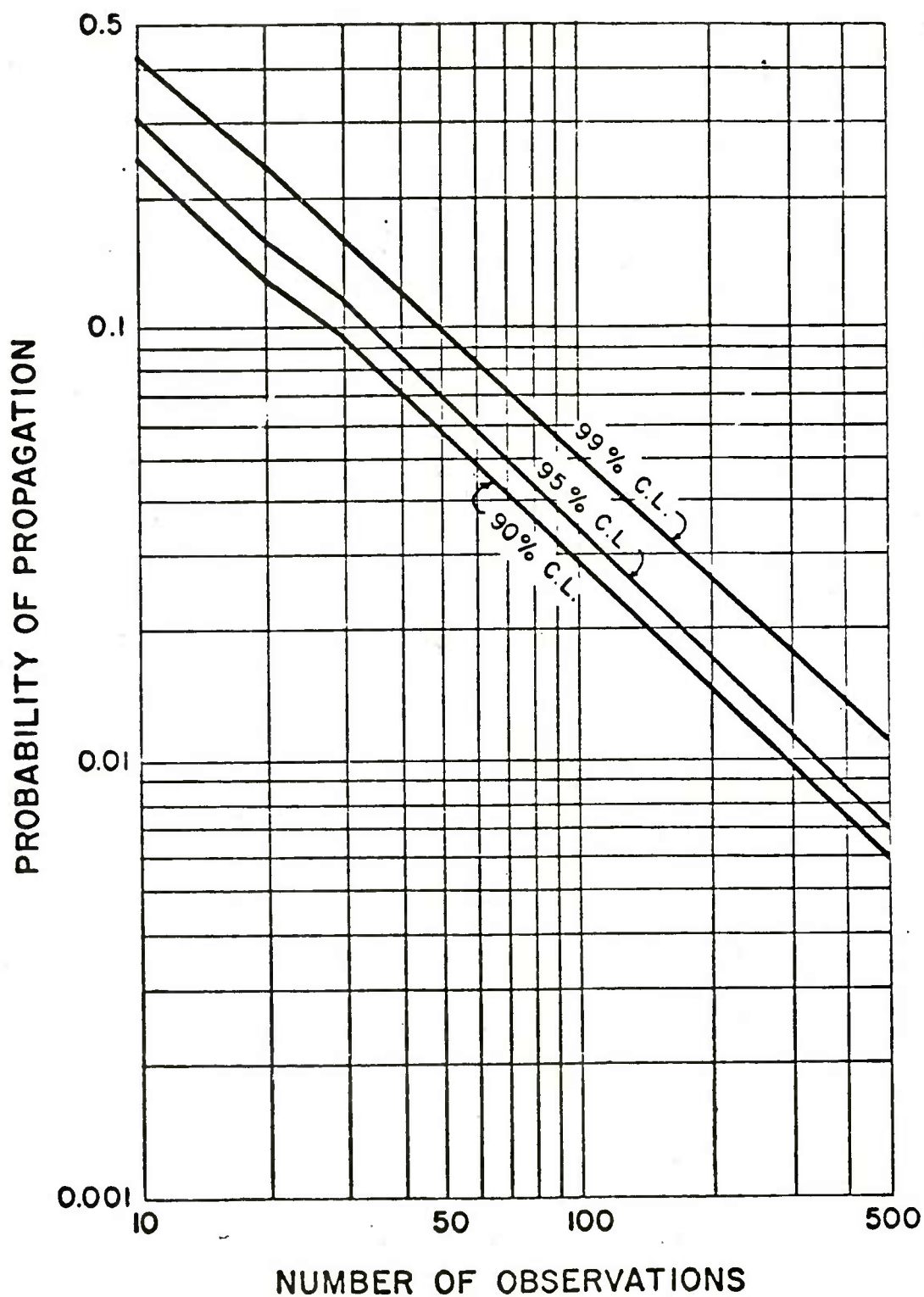| Number of observations n	90% p_2	C.L. $E(x)$	95% p_2	C.L. $E(x)$	99% p_2	C.L. $E(x)$
10	0.259	2.59	0.308	3.08	0.411	4.11
20	0.131	2.62	0.168	3.36	0.233	4.66
30	0.095	2.85	0.116	3.48	0.162	4.86
40	0.072	2.88	0.088	3.52	0.124	4.96
50	0.058	2.9	0.071	3.55	0.101	5.05
60	0.049	2.92	0.060	3.6	0.085	5.10
80	0.037	2.96	0.045	3.6	0.064	5.12
100	0.030	3.0	0.036	3.6	0.052	5.2
200	0.015	3.0	0.018	3.6	0.026	5.2
300	0.010	3.0	0.012	3.6	0.018	5.4
500	0.006	3.0	0.007	3.5	0.011	5.5

Figure A-1. Variation of propagation probability vs. number of observations as a function of confidence level

30

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